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Abstract

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This study was approved by the Human Subjects Research Review Board of the Office of the Surgeon General of the U.S. Army.

Director's Foreword

A critical need in the domain of personnel security is to obtain rapid, non-invasive, accurate measures of deception. For decades voice stress technologies have attempted to meet this need. During the past twenty years several instruments purported to detect stress in speech have appeared on the market. Additionally, several of these instruments claim accuracy rates that compete with the accuracy of polygraph examinations. However, little systematic research is available regarding the validity of these types of voice stress technologies. The present study was designed to investigate the computer voice stress analyzer (CVSA), which is one of several instruments commercially marketed to detect deception in voice. If validated, the availability of CVSA or any other non-invasive methodology capable of providing measures of deception would therefore have broad application and appeal. The validation of voice-based technologies for the detection of deception is a complex issue. Moreover, the results of several studies do not support the independent use of voice analysis for the purpose of detecting deception. However, the search for potential utility should continue. Future studies should refine the variables under investigation and attempt to answer more succinct research questions

William F. Norris

William F. Norris
Director

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Abstract

DoDPI Research Division Staff, MEYERHOFF, J. L., SAVIOLAKIS, G. A., KOENIG, M. L., & YOURICK, D. L. Physiological and biochemical measures of stress compared to voice stress analysis using the computer voice stress analyzer (CVSA). January 2001, Report No. DoDPI98-R-0004. Department of Defense Polygraph Institute, Fort Jackson, SC 29207. A number of features of the voice have been reported to reflect psychological stress. If these claims were validated, this technology could have significant medical and deception detection applications. Unfortunately, the reports have been inconsistent, possibly due to failure to utilize robust stress paradigms supported by validated physiological and biochemical indices of stress. Using a well-characterized stressful interview model, we examined the capabilities of a commercial computer voice stress analyzer (CVSA), which is purported to measure "physiological microtremor" or frequency modulation in the voice. Although a number of validated stress indices, including heart rate, blood pressure, plasma ACTH, and salivary cortisol, were all increased by the interview, no effect was seen in the CVSA data. Because of the potential medical value of a reliable voice stress analysis system, other available technologies assessing different voice features should be examined using this robust stress paradigm.

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During the past twenty years several instruments purported to detect stress in speech have appeared on the market. A number of these instruments have found their way into law enforcement agencies as replacements or substitutes for the polygraph instrument and are being used as tools for the detection of deception. However, these instruments have not been validated in controlled laboratory experiments. A technology which could quantify psychological stress based on properties of the voice, if validated, could also have a number of medical applications, unrelated to detection of deception. One such potential application might be psychophysiological assessment of stress, with possible interface with telemedicine. The present study was designed to investigate the computer voice stress analyzer (CVSA), which is one of several devices that have been commercially marketed to detect psychophysiological stress in the voice.

The most common measure of interest for voice stress analyzers is microtremor. This has been described as a low frequency (typically 8 to 14 Hz), low amplitude oscillation of the reflex mechanism controlling the length and tension of a stretched muscle (Lippold, 1971). This tremor is believed to be a function of the signals to and from motor neurons, and is analogous to a self-adjusting (hunting), closed loop servo system. Stretch sensors in the muscle tissue signal the amount of stretching and transmit this information to the associated motor neuron in the spinal cord. The efferent motor neuron fiber is then activated to increase or decrease the stretch of the muscle tissue. The finite delays in signal transmissions to and from the target muscle account for the low frequency oscillation.

Voice stress analyzers are said to detect physiological microtremor in speech and convert the tremor components to a graphical representation of stress experienced by the participant (Brenner, Branscomb, & Schwartz, 1979). Nerve fibers in the trunk of the vagus nerve innervate the laryngeal muscles, including the cricothyroid muscle (Kahane, 1986). Increases in voice frequency are accomplished by lengthening the vocal folds through activity of the cricothyroid muscle, while decreases are attributable to relaxation and shortening of the vocal folds by the thyroarytenoid (Gray, 1977, p. 963). The magnitude of laryngeal microtremor, which is indirectly assessed by analysis of changes in voice fundamental frequency, is purported to be inversely related to stress (Brenner, et al., 1979; Inbar & Eden, 1976, Smith, 1977; VanDercar, Greaner, Hibler, Spielberger, & Block, 1980). Some researchers have suggested that voice stress is linked to deception (Motley, 1974; O'Hair & Cody, 1987; Streeter, Krauss, Geller, Olson, & Apple, 1977). Microtremor in speech could be considered a frequency modulated (FM) signal. In other words, the fundamental speech frequency (e.g., 140 Hz) could theoretically have the microtremor component impressed on it, such that the fundamental signal could vary either side of 140 Hz at a rate equal to the microtremor frequency. However, others have found no evidence to support the existence of microtremor in human speech (Shipp & Izdebski, 1981). They examined electromyographic (EMG) activity directly from the cricothyroid and posterior cricothyroid during sustained phonation and conversational speech. These signals were compared to normal microtremor of 9 Hz sampled from the biceps. Conversely, Inbar and Eden (1976), using similar techniques, found evidence that EMG recordings were correlated with

frequency changes in speech, suggesting the existence of voice microtremor.

Several studies have been conducted using the computer voice stress analyzer (CVSA) to analyze speech for indices of deception. In a study conducted prior to participant testing (Cestaro, 1996a), the CVSA instrument was analyzed in the laboratory to determine if it performed electronically as described by the manufacturer. The results of this study demonstrated that the instrument functioned according to theory when stimulated by electronically generated signals. However, subsequent tests using human participants failed to find evidence to support the notion that the instrument was capable of detecting stress under low to moderately stressful conditions (Cestaro, 1996b, 1996c; Janniro & Cestaro, 1996). Data from recent analog studies of the psychophysiological detection of deception (PDD), using a polygraph instrument, consistently reveal effect sizes smaller than those reported in the field (Cestaro, 1996c; Ingram, 1996a, 1996b, Honts & Carlton, 1990). The low accuracy rates obtained in the laboratory have frequently been attributed to a lack of psychological stress experienced by participants because of the non-threatening nature of the laboratory scenario. Not surprisingly, proponents of the CVSA also claim that the lack of jeopardy (and hence, stress) is responsible for the subsequent low accuracy rates obtained using the CVSA in laboratory conditions. However, this line of reasoning does not account for the high false positive rates obtained in CVSA laboratory studies. In addressing the detection issues, PDD researchers are faced with the problems of designing a realistic or high stress scenario that will not violate ethical principles or infringe on participants' rights. Additionally, there has been no reliable method proposed that would allow the assessment of stress levels independently of the polygraph test, presenting a problem of circularity for PDD researchers.

Medical research has shown that there are circulating humoral factors in the blood and physiological responses that are associated with psychological stress (Oleshansky & Meyerhoff, 1992; Meyerhoff, Oleshansky, Kalogeras, Mougey, Chrousos, & Granger, 1990; Meyerhoff, Oleshansky, & Mougey, 1988a; 1988b). In these previously reported studies, a stressful interview elicited marked increases in heart rate (HR) and plasma levels of stress-related hormones, compared with baseline values. Increases in blood pressure (BP) were also seen.

We required a paradigm which afforded the opportunity to study the effect of purely psychological stressors on physiological and neuroendocrine indices of stress while also providing data related to possible indices of stress in participants' voice responses. In addition to controlling for postural changes, it was also essential to control for the diurnal variation which is present in hormones such as cortisol (CS), and to eliminate the potentially confounding effect of physical exertion. The availability in our laboratory of technology for ambulatory physiological monitoring and collection of blood, assays for peripherally secreted hormones, as well as state-of-the-art assays for potentially stress-responsive pituitary peptides provided additional means to develop an optimized paradigm.

Oral presentations, oral exams and evaluative interviews are a rite of passage in many professions and occupations, including the military. The salient features of such events include: (a) public speaking, (b) formal presentation before a number of higher-ranking members of a profession, and (c) submitting to evaluation. As part of their training and preparation for

promotion boards, soldiers at the Walter Reed Army Institute of Research (WRAIR) are encouraged to appear before "Soldier of the Month" (SOM) Boards -- contests held monthly to select and honor an outstanding soldier. Soldiers are encouraged to use the SOM Boards as training and preparation for their promotion boards. Hence the SOM Boards are patterned after promotion boards and are rigorous, competitive, structured interviews conducted by a panel comprised of senior non-commissioned officers. Contestant performance is scored by the panel based on knowledge of job-related subject matter, personal appearance, military bearing and quality of oral presentation. The contestants represent a range of ranks, including Private First Class, Specialist and Sergeant. The panels consist of six or seven senior non-commissioned officers, usually including several Staff Sergeants, and a Sergeant First Class or Master Sergeant. The Company Sergeant Major or First Sergeant usually serves as president of the Board. The candidate soldier is both outnumbered and outranked while facing this panel, which may account in part for the robustness of the stress response in this paradigm.

The winning contestant is awarded a $50.00 savings bond, a weekend pass, a certificate of achievement and an opportunity to compete at higher levels of competition in the future. In addition the winner is exempt from ancillary duties for one month. Also a press release is sent to the winner's hometown newspaper and his/her photograph is displayed in the lobby of the Institute. Candidates who do not win are subjected to no penalties and may enter subsequent competitions as often as they wish. Participation in this research study was in no way a requirement or a factor in the determining the winner of the Board. Participants in the study were candidates in the monthly competitions who volunteered to serve as participants after being fully informed about the experimental procedures. All gave written informed consent for us to monitor their BP and HR, to take salivary samples and, in some volunteers, to draw blood samples before, during, and after their exam, as well as for administration of psychometric questionnaires before and after the board.

We have characterized this competition as a model for studying endocrine responses to stressful social interactions in an occupational setting. Undertaking such a study requires satisfying several conditions: the participants must be protected (e.g. fully-informed volunteers), yet the paradigm should be stressful; the situation should be occupationally relevant, yet permit rigorous experimental control without undue interference on the part of the experimenters. The SOM paradigm meets these criteria.

Methods

Participants

Twenty-two participants volunteered to participate in this study. The typical participant was physically fit, was a specialist, corporal, or sergeant in the U.S. Army, and was assigned as a research technician at the Walter Reed Army Institute of Research (WRAIR). Participants' ages ranged from 20 to 35 years (M = 25.4 years). Seven participants were female and fifteen were male. Blood was drawn only on male participants, but salivary samples were taken from both male and female volunteers.

Description of Board and voice sampling paradigm

Stressors are usually characterized as acute, repeated, or chronic. A rite of passage, such as a promotion exam or the SOM Board is a relatively acute stressor, in the context of the day of the interview. There is also some anticipatory stress on the morning of the interview (e.g. slightly elevated HR) compared to a week prior to the interview. Acute stress responses might be defined as phasic, e.g. lasting a few seconds, or tonic, e.g. lasting minutes to hours. In PDD experiments, one might expect phasic responses. Indeed, a "relevant" question might be embedded in a context of irrelevant or neutral questions. A significant phasic autonomic nervous system response (e.g. HR, BP, or electrodermal response) might be expected to the "relevant" question. The present experiment was not designed to measure instantaneous or phasic responses to a "relevant" question. The intent was rather to examine whether the CVSA technology would identify changes in voice features which coincided with the highly predictable and robust humoral and physiological responses which have been well-validated indices of psychological response to exposure-acute (tonic) social stressors, such as the SOM Board (Meyerhoff, Oleshansky, & Mougey, 1988). We have found that these responses peak 5 minutes after participants are seated before the panel of interviewers. In order to obtain a voice sample during this peak period without disrupting the social context, a series of six questions was designed such that they were militarily-relevant, and that the correct answer was always "no". Participants were given these questions (as well as the answers) at least a week prior to the interview. Moreover, the participants were asked the six questions (asked by an experimenter) and their answers were recorded on six other occasions: seven days before, two days before, 30 minutes before, 30 minutes after, two days after, and seven days after the board. Thus these were familiar, "neutral" questions embedded in the context of an interview which has been well-established as a potent social stressor.

Apparatus

Two hours before the exam, electrodes were placed on the participant's chest and a BP cuff placed on the participant's right arm, both connected using wire leads to an Accutracker (TM) [SunTech Medical Instruments, Inc., 8917 Glenwood Avenue, Raleigh, NC 27612, USA] monitor worn on a belt for recording HR and BP every 5 minutes. In a subset of male participants (N=6) who volunteered to undergo venipuncture, a sterile intravenous needle was then inserted into the anterior cubital vein of the left arm and blood was collected through non-thrombogenic tubing using a 3-speed blood withdrawal pump (Model #6-53R, Cormed Inc., Medina, NY) also worn on the belt. A cylindrically-shaped plastic arm board was worn on the left arm to prevent flexion. Blood was withdrawn continuously at 0.1 ml/min throughout the procedure, except during discreet sampling intervals when pump speed was increased to 5 ml/min. All apparatus was concealed under the uniform jacket. Blood was sampled at 7 time points on the day of the exam. Each blood sample consisted of two sequential 10 ml samples collected in chilled tubes containing EDTA and kept on ice until centrifuged at 4°C. The plasma samples from these two tubes were mixed and aliquoted into tubes containing 50 ul (22 T.I.U./ml) of aprotinin (a protease inhibitor) for adrenocorticotropic hormone (ACTH) assays. These tubes, as well as a tube of untreated plasma for CS assays were frozen at -70°C until assayed. The values reported represent an integrated four-minute blood collection beginning at the scheduled sampling point. Using Salivette (TM) [Sarstedt Ltd., 68 Boston Road, LEICESTER, United Kingdom LE4 1AW] tubes, we collected salivary samples before and after

(but not during) the exam. Salivary samples were frozen at -70°C until assayed for CS. Voice responses were collected using a digital audio tape (DAT) recorder (Panasonic Corporation, Model SV-3700). A lavaliere microphone (Shure Corporation, Model 570S) was placed on the participant to provide audio to the tape recorder. Voice responses were transferred from the tape recorder directly to 50mm chart paper using a computer voice stress analyzer instrument (NITV, model CVSA).

Interview procedure

Each candidate was examined individually by the panel for approximately 30 minutes. The conduct of the SOM interview followed a standard routine. First, the soldier knocked on the door, entered the room and saluted. The soldier then responded to a series of military commands issued by the president of the board (e.g. "right face", "left face", "about face"). He was then invited to sit in a chair placed before the board, and upon direction of the president of the board, the participant delivered a brief oral description of his military career, usually including training, assignments, education and future plans. Then the panel began asking questions. Most of the questions were selected from a printed study guide, which was made available to all candidates. The questions related to the skills and duties required of all soldiers. For soldiers volunteering to be participants in this study, 5 minutes after his or her being seated, a microphone was placed around the soldiers neck and the president asks the six "neutral" questions.

Data Collection Procedure

To minimize any effects of diurnal variation, participants with intravenous catheters were always scheduled to appear before the panel at either 9:00 or 9:30 A.M. We used a nearby room as a waiting room to provide them with a constant environment for 30 minutes before and after the exam.

We measured physiological (HR and BP) and plasma hormonal responses before, during, and after the Board. Salivary samples were taken before and 5 minutes after, but not during the board. All apparatus was concealed beneath the Class A uniform. Psychological responses were estimated via self-report questionnaires (e.g. the Spielberger State/Trait Anxiety Index questionnaire) administered before and after the interview. Blood was sampled at multiple time points on the morning of the Board, including sitting, at rest, waiting to be called for the Board interview; 5 minutes after being seated before the panel of examiners in the interview; 20 minutes after being seated before the panel; 5 minutes after returning to the waiting room and being seated; and 20 minutes after returning to the waiting room and being seated.

Voice responses were transferred to CVSA charts from DAT. The CVSA charts were then randomly ordered in three sets for blind scoring such that pre interview, interview, and post interview periods were not in consecutive order. Additionally, different participant numbers (i.e., aliases) were assigned within each of the three sets. The three CVSA judges were blind to the experimental design and conditions. The judges were instructed to assign numerical stress scores to each response as taught by the equipment manufacturer.

Results

Although 22 participants were studied, only six participants volunteered to have blood drawn. HR, BP, and ACTH levels were significantly increased during the board examination when compared to pre and post-test levels (Figure 1). However, CVSA scores did not parallel these biomedical measures (Figure 2). Repeated measures analyses of variance (ANOVA) were used to test the hypothesis that data from any one or more test periods were significantly different from the rest of the test periods. Although the biomedical measures showed a significant effect of stress level, this was not the case for the CVSA scores (Table 1). Planned contrasts, which tested a priori hypotheses regarding particular test periods (especially test period 4, the SOM interview), conformed to predictions when the biomedical data were examined, as shown in Table 2, but did not for the CVSA data. Intercorrelations among the three CVSA judges (Table 3) were not statistically significant ($p > .05$), indicating little agreement among scores assigned to voice responses.

Table 1
Results of Repeated Measures Analyses of Variance

Variable	N	F	p
Heart rate	22	23.77	<.001
Systolic Blood Pressure	19	81.44	<.001
Diastolic Blood Pressure	19	13.91	<.001
Salivary Cortisol	22	3.78	.002
ACTH	6	9.04	<.001
CVSA – Judge 1	22	1.27	.278
CVSA – Judge 2	22	1.26	.282
CVSA – Judge 3	22	0.72	.636

Table 2
Planned Contrasts for Biomedical Measures and CVSA Scores

Variable	N	F	p
Heart rate	22	36.09	<.001
Systolic Blood Pressure	19	162.52	<.001
Diastolic Blood Pressure	19	43.61	<.001
Salivary Cortisol	22	11.67	.003
ACTH	6	18.41	.007
CVSA – Judge 1	22	1.87	.186
CVSA – Judge 2	22	1.18	.289
CVSA – Judge 3	22	1.94	.179

Table 3
Intercorrelations Among CVSA Judges

Judge	1	2
2	.34	
3	.34	.32

Discussion

The stressfulness of this paradigm is well established. We have previously reported increases in self-reported anxiety scores (Spielberger State Anxiety Scale) immediately before and after the Board, compared to one week prior (Glass, Arnkoff, Wood, Meyerhoff, Smith, Oleshansky, & Hedges, 1995). Anxiety was reduced by two days after the Board, and by seven days it was significantly lower than reported one week before the Board. High levels of anxiety before the Board were related to poor performance and lower Board scores, whereas high self-efficacy ratings and a high ratio of positive to negative thoughts were associated with better performance (Glass et al., 1995).

In the present study, voice samples, HR, BP and plasma samples were all taken approximately five minutes after the participant was seated in front of the panel of interviewers. HR, BP, and plasma ACTH all increased significantly, confirming that this was, as expected, a period of peak response to the social stressor. Salivary CS, measured in 22 participants before and shortly after the interview, showed a significant post-interview elevation, providing further confirmation of the overall stressfulness of the interview. The CVSA scores, although taken at the same time as the HR, BP, and ACTH measures, failed to reflect the stressfulness of the situation. Accordingly, it does not appear that the CVSA analysis of voice features reflects well-validated tonic responses to acute social stress. While not addressing the capability of this equipment to detect transient, phasic responses to exposures to acute stress, these studies do not support a role for the CVSA as an ancillary measure of psychological stress.

Occupational, clinical and laboratory paradigms as well as sporting events have been used in studies of physiological responses to environmental stressors. Public speaking in an occupational environment (physicians presenting at a medical conference) was associated with increases in HR equal to those seen after moderate exercise (Moss & Wynar, 1970). In more recent studies, high CS levels were seen despite administration of dexamethasone, an agent which indirectly inhibits CS secretion (Baumgartner, Graf, & Kurten, 1985). Also, examinations have been reported to increase HR (Lovallo, Pincomb, Edwards, Brackett, & Wilson, 1986) and urinary levels of CS in students (Lovallo et al., 1986; Frankenhaeuser, Von Wright, Collins, Von Wright, Sedvall, & Swahn, 1978).

Endocrine changes have also been reported in individuals anticipating various types of challenge. In hospital settings, elevated plasma levels of CS were reported in patients waiting imminent surgical procedures (Czeisler, Moore Ede, Regestein, Kisch, Fang, & Ehrlich, 1976).

Elevated plasma CS was also found in participants about to commence vigorous exercise (Hartley et al., 1972), and increases in ACTH (Oltras, Mora, & Vives, 1987) were seen in trained long distance runners 20 minutes before a race.

In laboratory studies using human volunteers, a mental arithmetic task was reported to produce increases in HR and BP (Lane, White, & Williams, 1984) as well as increases in plasma CS levels (Williams, Lane, Kuhn, Melosh, White, & Schanberg, 1982). In studies of patients with phobic symptoms, exposure to phobic stimuli increased anxiety, HR, BP, CS (Nesse, Curtis, thyer, McCann, Huber-Smith, & Knopf, 1985) and urinary excretion of CS (Fredrickson, Sundin, & Frankenhaeuser, 1985). Whereas the biomedical measures in our study were related to stress levels, this was not true for the voice stress measures. Previous research has also failed to provide evidence that the CVSA can reliably detect stress in human voice responses (Cestaro, 1996b, 1996c; Janniro & Cestaro, 1996). Additionally, the low interrater reliability among the CVSA judges casts doubt on the validity of the instrument for the detection of stress related to the act of deception. The low reliability could be attributable to inadequate training of examiners, poor instrument sensitivity, a flawed physiological theory of operation, or a combination of these factors. Any one of these factors could lead to Type II errors with respect to stress measures in speech responses. Additionally, this experiment did not specifically address the question of the possible interaction of interview stress on the potential of this instrument to detect phasic responses to an individual stressful question.

It should also be noted that the CVSA has been associated with a high false positive rate in previous studies using a mock-crime scenario (Cestaro, 1996a, 1996b). This high false positive rate cannot be explained by the lack of jeopardy in these participants because a lack of jeopardy should produce a preponderance of false negative outcomes. Although we do not find a basis for recommending use of CVSA technology for medical assessment of stress nor for the detection of deception, the utility of other voice stress analytic technologies is not ruled out and should be examined. For example, it is known that, in addition to fundamental frequency, changes in the arrangement of formants during vowel production is also influenced by increases in arousal level (Pollina, Vacoch, and Wurm, 1998). More research is needed before conclusive statements can be made about the utility of voice stress technologies for use in the psychophysiological detection of deception.

References

Baumgartner, A., Graf, K. J., & Kurten, I. (1985). The dexamethasone suppression test in depression, in schizophrenia, and during experimental stress. Biological Psychiatry, 20, 675-679.

Brenner, M., Branscomb, H. H., & Schwartz, G. (1979). Psychological stress evaluator--two tests of a vocal measure. Psychophysiology, 16(4), 351-357.

Cestaro, V. L (1996a). A test of the computer voice stress analyzer (CVSA) theory of operation. Polygraph, 25, 101-116.

Cestaro, V. L. (1996b). A comparison between decision accuracy rates obtained using the polygraph instrument and the computer voice stress analyzer (CVSA) in the absence of jeopardy. Polygraph, 25, 117-127.

Cestaro, V. L. (1996c). A comparison of accuracy rates between detection of deception examinations using the polygraph and the computer voice stess analyzer in a mock crime scenario (Report No. DODPI95-R-0004). Fort McClellan, AL: Department of Defense Polygraph Institute.

Czeisler, C. A., Moore Ede, M. C., Regestein, Q. R., Kisch, E. S., Fang, V. S., & Ehrlich, E. N. (1976). Episodic 24-hour cortisol secretory patterns in patients awaiting elective cardiac surgery. Journal of Clinical Endocrinology & Metabolism, 42(2), 273-283.

Frankenhaeuser, M., Von Wright, M. R., Collins, A., Von Wright, J., Sedvall, G., & Swahn, C. G. (1978). Sex differences in psychoneuroendocrine reactions to examination stress. Psychosomatic Medicine, 40(4), 334-343.

Fredrikson, M., Sundin, O., & Frankenhaeuser, M. (1985). Cortisol excretion during the defense reaction in humans. Psychosomatic Medicine, 47(4), 313-319.

Glass, C.R., Arnkoff, D.B., Wood, Meyerhoff, J.L., Smith, H.R., Oleshansky, M.A., Hedges, S. (1995). Cognition, anxiety and performance on a career-related oral examination. Journal of Counseling Psychology. 42(1), 47-54.

Gray, H. (1977). The organs of voice and respiration. In: T. P. Pick & R. Howden (Eds.), Gray's anatomy (pp. 955-983). New York: Gramercy Books.

Honts, C. R., & Carlton, B. (1990). The effects of incentives on the detection of deception (Report No. DODPI90-R-0003). Fort McClellan, AL: Department of Defense Polygraph Institute.

Inbar, G. F., & Eden, G. (1976). Psychological stress evaluators: EMG correlation with voice tremor. Biological Cybernetics, 24, 165-167.

Ingram, E. M. (1996a). Test of a mock theft scenario for use in the psychophysiological detection of deception: I (Report No. DODPI96-R-0003). Fort McClellan, AL: Department of Defense Polygraph Institute.

Ingram, E. M. (1996b). Test of a mock theft scenario for use in the psychophysiological detection of deception: II (Report No. DODPI97-R-0003). Fort McClellan, AL: Department of Defense Polygraph Institute.

Kahane, J. C. (1986). Anatomy and physiology of the speech mechanism. In: H. Halpern (Ed.), The Pro-Ed studies in communicative disorders, (pp. 78-93). New York: Pro-Ed.

Janniro, M. J., & Cestaro, V. L. (1996). Effectiveness of detection of deception examinations using the computer voice stress analyzer (Report No. DODPI96-R-0005). Fort McClellan, AL: Department of Defense Polygraph Institute.

Lane, J. D., White, A. D., & Williams, R. B. Jr. (1984). Cardiovascular effects of mental arithmetic in type A and type B females, Psychophysiology, 21(1), 39-46.

Lippold, O. (1971). Physiological tremor. Scientific American, 224, 65-73.

Lovallo, W. R., Pincomb, G. A., Edwards, G. A., Brackett, D. J., & Wilson, M. F. (1986). Work pressure and the type A behavior pattern exam stress in male medical students. Psychosomatic Medicine, 48(1/2), 125-133.

Mason, J. W. (1968). Over-all hormonal balance as a key to endocrine organization. Psychosomatic Medicine, 30, 791-808.

McEwen, B. S., Wallach, G., & Magnus, C. (1974). Corticosterone binding to hippocampus: Immediate and delayed influences of the absence of adrenal secretion. Brain Research, 70, 321-334.

Meyerhoff, J. L., Oleshansky, M. A., Kalogeras, K. T., Mougey, E. H., Chrousos, G. P., & Granger, L. G. (1990). Neuroendocrine responses to emotional stress: Possible interactions between circulating factors and anterior pituitary hormone release. In J. C. Porter & D. Jezova (Eds.), Circulating regulatory factors and neuroendocrine function (pp. 91-111). New York: Plenum Press.

Meyerhoff, J. L., Oleshansky, M. A., & Mougey, E. H. (1988a). Psychologic stress increases plasma levels of prolactin, cortisol, and POMC-derived peptides in man. Psychosomatic Medicine, 50, 295-303.

Meyerhoff, J. L., Oleshansky, M. A., & Mougey, E. H. (1988b). Effects of psychological stress on pituitary hormones in man. In G. P. Crousos, D. L. Loriaux, & P. W. Gold (Eds.), Mechanisms of physical and emotional stress (pp. 465-478). New York: Plenum Press.

Moss, A. J. & Wynar, B. (1970). Tachycardia in house officers presenting cases at grand rounds. Annals of Internal Medicine, 72(2), 255-256.

Motley, M. T. (1974). Acoustic correlates of lies. Western Speech, 81-87.

Nesse, R. M., Curtis, G. C., Thyer, B. A., McCann, D. S., Huber-Smith, M. J., & Knopf, R. F. (1985). Endocrine and cardiovascular responses during phobic anxiety. Psychosomatic Medicine, 47(1), 320-332.

O'Hair, D, & Cody, M. J. (1987), Gender and vocal stress differences during truthful and deceptive information sequences. Human Relations, 40, 1-14.

Oleshansky, M. A., & Meyerhoff, J. L. (1992). Acute catecholaminergic responses to mental and physical stressors in man. Stress Medicine, 8, 175-179.

Oltras, C. M., Mora, F., & Vives, F. (1987). Beta-endorphin and ACTH in plasma: Effects of physical and psychological stress. Life Sciences, 40, 1683-1686.

Pollina, D.A., Vacoch, D.R., and Wurm, L.H. (1998). Formant structure of vowels spoken during attempted deception. Polygraph, 27, 96-122.

Shipp, T., & Izdebski, K. (1981). Current evidence for the existence of laryngeal macrotremor and microtremor. Journal of Forensic Sciences, 26, 501-505.

Smith, G. A. (1977). Voice analysis for the measurement of anxiety. British Journal of Medical Psychology, 50, 367-373.

Streeter, L. A., Krauss, R. M., Geller, V., Olson, C., & Apple, W. (1977). Pitch changes during attempted deception. Journal of Personality and Social Psychology, 35(5), 345-350.

Tolkmitt, F. J., & Scherer, K. R. (1986). Effect of experimentally induced stress on vocal parameters. Journal of Experimental Psychology, 12, 302-313.

VanDercar, D. H., Greaner, J., Hibler, N. S., Spielberger, C. D., & Block, S. (1980). A description and analysis of the operation and validity of the psychological stress evaluator. Journal of Forensic Sciences, 25, 174-188.

Williams, R. B. Jr., Lane, J. D., Kuhn, C. M., Melosh, W., White, A. D., & Schanberg, S. M. (1982). Type A behavior and elevated physiological and neuroendocrine responses to cognitive tasks. Science, 218, 483-485.

Figure Legends

Figure 1. Mean (± S.E.M.) Physiological and Biochemical responses at seven points before (Timepoints 1-3), during (Timepoint 4), and after (Timepoints 5-7) the interview process. Salivary cortisol samples were obtained before, and five minutes after (but not during) the board interview.

Figure 2. Mean (± S.E.M.) CVSA responses to six neutral questions asked at seven points before (Timepoints 1-3), during (Timepoint 4) and after (Timepoints 5-7) the interview process.

Figure 1: Physiological and Biochemical Measures

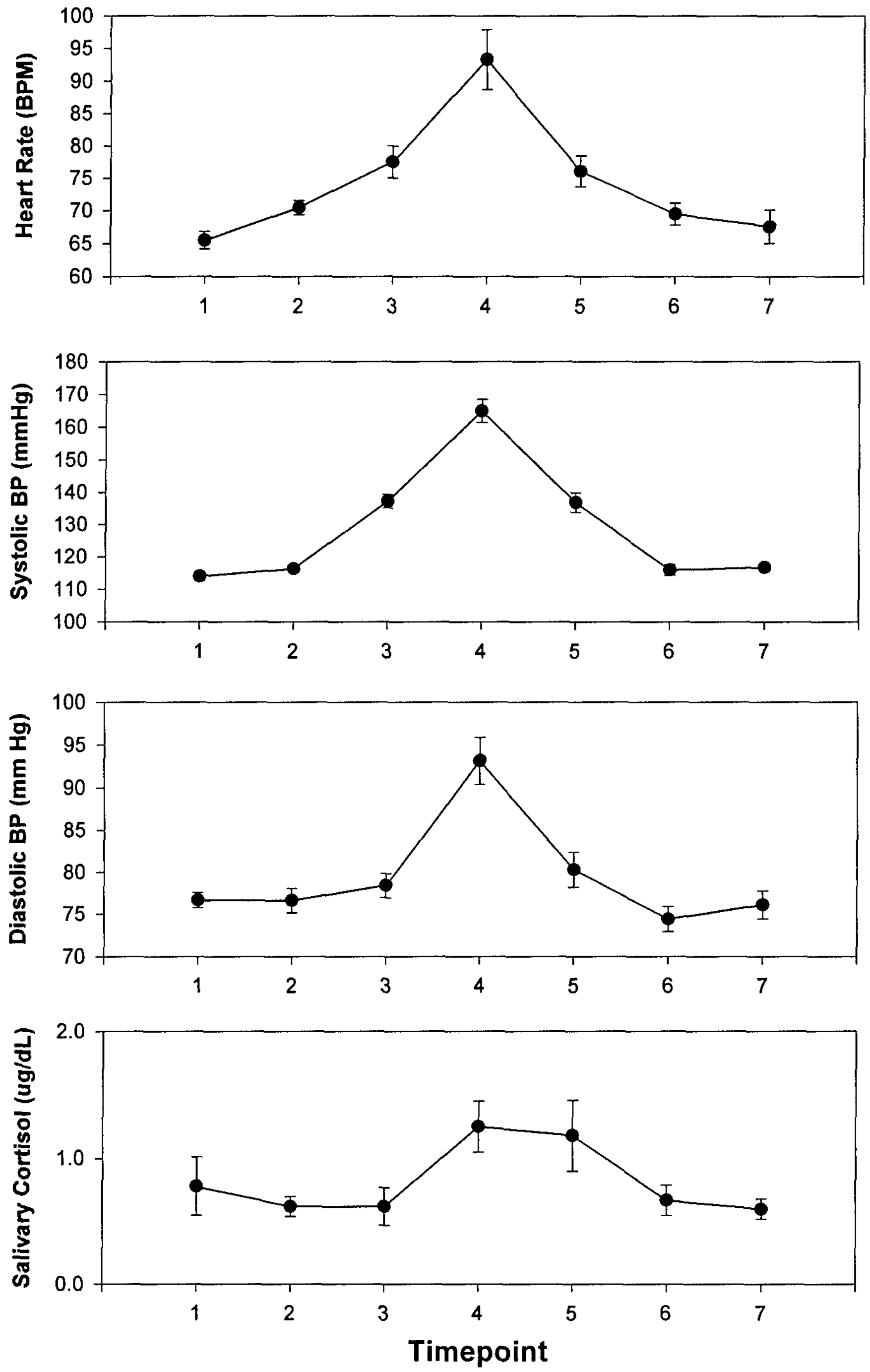
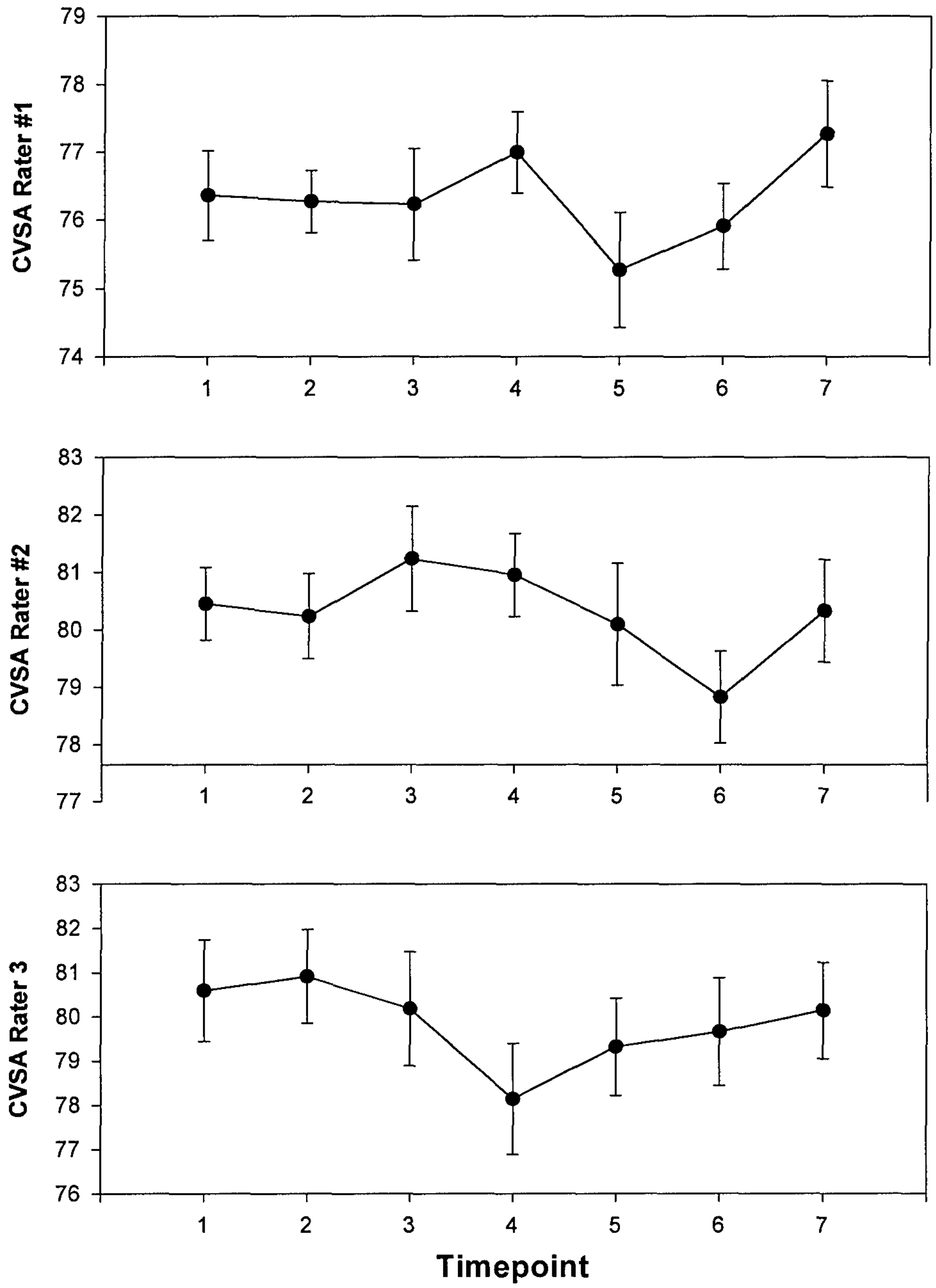


Figure 2: CVSA Responses



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